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COMMON CHUCKWALLA (*SAUROMALUS ATER*) POPULATIONS IN THE PHOENIX METROPOLITAN AREA: STABILITY IN URBAN PRESERVES

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***Abstract.*—Currently, there is considerable interest in the response of reptile populations to habitat fragmentation and degradation due to urbanization. We surveyed populations of the Common Chuckwalla (*Sauromalus ater*) in preserves of the Phoenix Mountains and adjacent areas near the Phoenix Metropolitan region during the spring of 2008. Fecal dropping counts were used to assess the current populations in relation to those sampled in 1995. Our results revealed a strong correlation between estimates gathered in 1995 and 2008. Additionally, one intensively sampled site established that, although estimates could vary somewhat in relation to the number of individuals conducting the survey, they were stable over a 13 year period. Overall, survey results suggest that Common Chuckwalla populations are stable in these island preserves in a sea of urban development.**

Key Words.—Common Chuckwalla; indirect survey; preserves; reptile conservation; *Sauromalus ater*; urban wildlife

INTRODUCTION

Conversion of natural areas to urban landscapes with isolated patches of remaining habitat is occurring at an ever increasing rate (Goffette-Nagot 2000). There is a growing literature regarding the significance of such habitat fragmentation and loss for respective animal populations (e.g., Faeth et al. 2005; Lindenmayer and Fischer 2006; Garden et al. 2007). Investigators have documented changes in the behavior of a variety of mammals and birds in urban settings with fragmented landscapes, including canids (e.g., Atwood et al. 2004; Riley 2006), procyonids (Prange and Gehrt 2004), artiodactylids (Harveson et al. 2007), and corvid birds (Marzluff and Neatherlin 2006). Although these studies documented behavioral changes of individual species, it remains to be seen whether these organisms will persist in these altered habitats. Extirpation of a single species, especially a reptile, may appear inconsequential to most, but Faeth et al. (2005) argued convincingly that the loss of reptilian predators in urban preserves could have far reaching consequences for trophic interactions and resultant community dynamics.

Although birds and mammals have received the most attention, increasingly studies have focused on habitat change and fragmentation effects on reptiles (MacNally and Brown 2001; Garden et al. 2007). An initial area of interest for those working with amphibians and reptiles was the importance of roadways with respect to animal movement and mortality (e.g., Rosen and Lowe 1994; Row et al. 2007; Glista et al. 2008). Impacts on community composition for reptiles and amphibians inhabiting preserves within urbanized landscapes (e.g., Koenig et al. 2001; Garden et al. 2007) or experiencing other aspects of anthropogenic habitat alteration (e.g., Sullivan 2000; Sullivan et al. 2005; Kwiatkowski et al., in press) are also receiving greater attention. It is increasingly clear from recent studies that reptilian species respond individualistically to preserve size and structure. For example, Garden et al. (2007) showed that habitat structure, rather than floristic composition, influenced reptile communities in Brisbane area preserves, and Koenig et al. (2001) found that unique aspects of the behavioral ecology of Blue-tongued Skinks (*Tiliqua scincoides*) allowed this relatively large lizard to persist in highly urbanized landscapes. The notion that larger preserves in and of themselves are the best approach in conservation efforts is being rethought as workers undertake more refined analyses of the relationships between habitat change and urbanization.

Habitat fragmentation and destruction due to urbanization is occurring throughout the United States,

FIGURE 1. A juvenile Common Chuckawalla (*Sauromalus ater*). (Photo by: Brian Sullivan).

but especially in the Phoenix metropolitan area of the desert Southwest. In this region, native Sonoran Desert habitat is being fragmented and isolated as a result of widespread development (Knowles-Yanez et al. 1999; Faeth et al. 2005). The relatively larger lizards and snakes appear especially vulnerable to the impacts of urbanization in this region (e.g., Sullivan and Flowers 1998). The Common Chuckwalla (*Sauromalus ater;* Fig. 1) is a large, herbivorous lizard inhabiting parts of California, Nevada, Utah, Arizona, and into Mexico, and has been studied extensively with respect to its reproductive biology (Kwiatkowski and Sullivan 2002a, b). Sullivan and Flowers (1998) found that chuckwallas were present in all preserves of the Phoenix Mountains with rocky outcrops and that larger preserves generally had higher densities of this lizard even though other large squamates (e.g., *Dipsosaurs dorsalis*) were absent or declining. In the interest of determining the response of chuckwalla populations to isolation in urban mountain preserves, we re-surveyed populations initially studied in 1995 to assess stability in populations over a 13 year period. A secondary interest was to determine the utility of an indirect survey method (fecal counts) to estimate population status of chuckwallas as assessed from one intensively monitored site.

METHODS

Study populations.—The Common Chuckwalla is relatively long-lived and extremely wary and difficult to census reptile (Sullivan and Flowers 1998; Sullivan et al. 2004a). Like some medium to large sized herbivores, however, its feces are distinctive and easily recognized. Typically, feces are deposited in obvious and exposed locations making the chuckwalla an excellent candidate for indirect survey methods (Sullivan and Flowers 1998). In the spring of 2008, we surveyed eight sites previously surveyed for feces in 1995 (Sullivan and Flowers 1998).

Sites were located in Sonoran Desert Upland (Brown

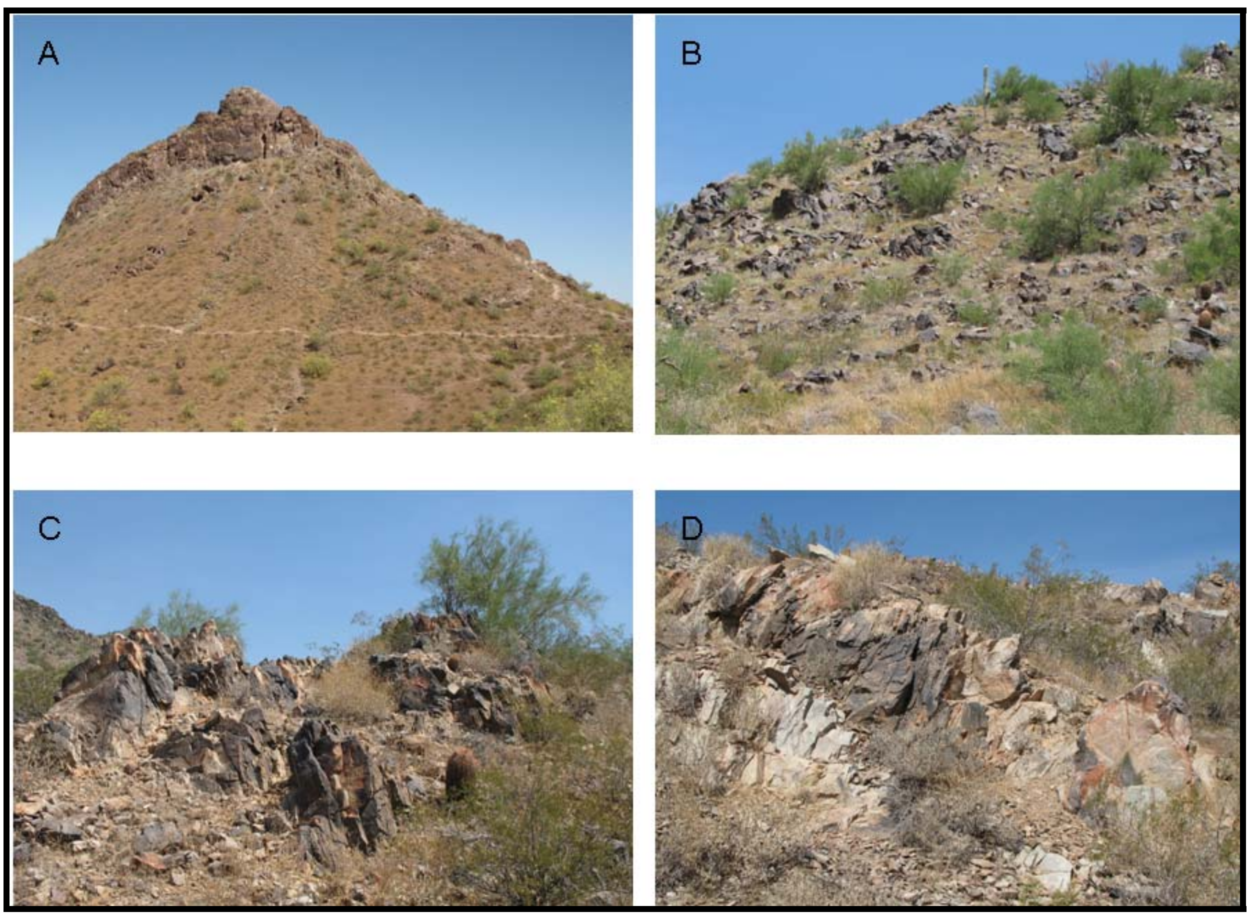

FIGURE 2. Selected sites of the Phoenix Mountains, Maricopa County, Arizona, USA. A: north face of Lookout Mountain (LM) showing absence of extensive rocky habitat (a low fecal count site) and sheer face used by rock-climbers. B: west slope of North Mountain (NM3) showing extensive rock formations used by chuckwallas (a high fecal count site). C and D: Piestewa Peak (PP) showing two areas with extensive damage to rocks, presumably due to breakage during collecting efforts or other off-trail activities (undamaged, stable rock surface is dark; recently disturbed rocks are light in color [white, grey or orange] due to the absence of dark "desert varnish").

1982), dominated by Saguaro Cactus (*Carnegiea gigantea*), Creosote (*Larrea tridentata*), Ocotillo (*Fouquieria splendens*), Foothill Palo Verde (*Parkinsonia microphyllum*), and Bursage (*Ambrosia deltoidea*). Rocky outcrops were available at each site, consisting of metamorphosed igneous rock (primarily schist and gneiss; Fig. 2). These consisted of six sampling sites within the Phoenix Mountains Preserve system: Lookout Mountain (LM), Piestewa Peak (PP), North Mountain Preserve one (NM1), two (NM2) and three (NM3), and Shadow Mountan (ShM); one site in the Hedgpeth Hills (HH, 20 km west of the Phoenix Mountains); and one site in the South Mountains (= SM, 30 km south of the Phoenix Mountains). Details on each of these sites, including precise locations, were provided in Sullivan and Flowers (1998).

Survey methods.—We followed the methodology of Sullivan and Flowers (1998) for counting fecal droppings of Common Chuckwallas at each site. Therein, they documented a strong correlation between total fecal dropping counts and total numbers of chuckwallas. In brief, this consisted of assigning a "count" for each basking site (i.e., a portion of a rock outcrop) of an approximately circular area (diameter = one m) sampled throughout a roughly one hectare area of chuckwalla habitat at each site within a preserve. Counts were tallied by a single observer over a one hour period, but we took care to sample the same area in 2008 that was surveyed in 1995. We then summed these counts to yield an overall score relative to those obtained in 1995.

All counts we obtained in 2008 were scored over a two week period in March after chuckwallas became active. We studied one site (PP in the Phoenix Mountains) intensively over the 13 years between primary samples. Groups of students (3-20) along with the senior author (supervising but not participating in count estimates) were used to sample this site repeatedly from 1997 through 2004. These surveys were conducted in the spring and fall each year, and often consisted of two groups collecting data on two days in both spring and fall that were averaged to yield a score for the year. In some instances, fewer than five students were available for surveys (see below).

Statistical methodology follows Hollander and Wolfe (1973); we used nonparametric tests exclusively because data were non-normal and samples sizes (i.e., number of sites) were small. Given the repeated measures design of the intensively monitored site, we used a nonparametric analog to repeated measures ANOVA, the Friedman test, to compare counts gathered over the 13 years at the Piestewa Peak site. We calculated a Spearman's rho correlation to compare 1995 and 2008 total counts for the eight sites.

TABLE 1. Fecal counts of Common Chuckwallas (*Sauromalus ater*) for eight sites in the Phoenix Mountains (PP ["Squaw Peak"], ShM, NM 1-3, LM), Hedgpeth Hills (HH; "Thunderbird") and South Mountains (SM), Arizona, USA in 1995 and 2008. The counts (totals) are highly correlated (r_s = 0.92, df = 6, P = 0.001). Each count category (e.g., 1-5 feces) represents the number of basking sites with that number of feces present at a given site in each year.

		Fecal Counts					
Site	**Year**	**1-5**	**6-10**	**11-15**	**16-30**	**>30**	**Totals**
PP	1995	12	3	3	3	1	22
	2008	20	7	0	1	1	29
ShM	1995	4	7	4	5	4	24
	2008	9	5	4	4	2	24
NM1	1995	3	0	0	0	0	3
	2008	5	0	0	0	0	5
NM2	1995	5	0	0	0	0	5
	2008	6	3	2	0	0	11
NM3	1995	12	5	2	2	1	22
	2008	17	3	1	2	0	23
LM	1995	4	1	2	1	1	9
	2008	4	2	0	1	0	7
HH	1995	5	3	0	2	0	10
	2008	11	0	0	0	0	11
SM	1995	10	8	7	5	8	38
	2008	29	7	2	3	4	45

RESULTS

We conducted surveys in 1995 (Table 1) during October, toward the end of the activity season of Common Chuckwallas in the Phoenix area (Kwiatkowski and Sullivan 2002a, b). During these surveys, we found many fresh feces and we observed a large number of active chuckwallas (i.e., basking). In 2008, considerable plant growth was available at all sites, and many feces were fresh. Although we devoted survey time at sites to conducting fecal counts, we observed more than 30 individual chuckwallas, primarily males, at or nearby the survey sites (i.e., basking, foraging). Hence, the lizards were active; air temperatures consistently reached 25^{o} C for the week prior to the surveys. Fecal counts from sites surveyed in 1995 were highly correlated with counts from the same sites surveyed in 2008 (r_s = 0.92, df = 6, P = 0.001, N = 8 sites). The distribution of count categories was similar as well; sites with basking areas with large numbers of feces in 1995 (e.g., ShM and SM) also had higher counts in the highest categories (Table 1).

For the one site (PP) that we surveyed repeatedly, from 1995 thru 2008, results indicated that total fecal counts could vary over time (Table 2), although this variation was due primarily to variation in the lowest count category (i.e., 1-5). This may have been due to the larger number of surveyors used in some of the surveys in 1997-2004 (generally between 10 and 20 surveyors) versus those with fewer (three to five surveyors: 1995, 2003, and 2008). Nonetheless, there was no significant variation (Friedman test statistic = 10.34, df = 8, P =

TABLE 2. Fecal counts of Common Chuckwallas (*Sauromalus ater*) for a single site in the Phoenix Mountains (PP), Arizona, USA over 13 years. Each count category (e.g., 1-5 feces) represents the number of basking sites with that number of feces present at a given site in each year. Ten or more surveyors participated in estimations during all years but 1995, 2003 and 2008 (one to three surveyors).

	Fecal Counts					
Year	**1-5**	**6-10**	**11-15**	**16-30**	**>30**	**Totals**
1995	12	3	3	3	1	22
1997	45	8	2	1	1	57
1998	32	9	1	1	0	43
1999	27	5	3	0	1	36
2000	33	5	2	1	1	42
2001	45	6	3	2	2	58
2003	23	2	2	1	1	29
2004	39	6	3	3	1	52
2008	20	7	0	1	1	29

0.24) in counts over time, indicating that this site was relatively stable in fecal counts over a 13 year period, similar to the results obtained for the eight sites sampled at the beginning (1995) and end (2008) of the survey period. Thus, results of both analyses suggest that chuckwalla populations were relatively stable at these sites from 1995 to 2008.

DISCUSSION

Alteration of natural landscapes due to urbanization is one of the most critical issues facing conservation biologists today (Brueckner 2000). The Sonoran Desert of southwestern North America has been extensively developed over the past five decades, especially in the Phoenix Metropolitan area (Knowles-Yanez et al. 1999; Sullivan et al. 2004b; Kwiatkowski et al., in press). Although other lizard species (e.g., *Dipsosaurus dorsalis, Gambelia wislizenii, Phrynosoma solare*) appear to have been extirpated from preserves of the Phoenix Mountains (Sullivan and Flowers 1998), the Common Chuckwalla is still found in all preserves regardless of size. Our results suggest that this large lizard is persisting in even the smallest preserves that have been set aside within a sea of urbanization.

Other studies suggest that squamates are often negatively impacted by habitat alteration, even when preserves of natural habitat are set aside. For example, the lacertid lizard, *Psammodromus algirus*, is apparently more attuned to variation in habitat quality (aspects allowing for thermoregulation, foraging opportunities) than preserve size (Santos et al. 2007). Hence, it may decline as a result of human activity in even large preserves if specific components of habitat quality are degraded. Martin and Lopez (2002) also found that Mediterranean lizard communities were sensitive to habitat alteration associated with anthropogenic changes; lizard assemblages were negatively impacted by a reduction in ground cover. Similar habitat associations have been detected for Sonoran Desert birds in Tucson; they generally respond to percentage cover in areas whether they are urbanized or natural, rather than simply avoiding urban areas (Turner 2006).

MacNally and Brown (2001) and Sarre et al. (1995) found that lizards with specialized niches were more likely to decline with increasing fragmentation and urbanization. Similarly, Kitchener et al. (1980) found that diversity of habitats within preserves was associated with lizard diversity; presumably, increased habitat variation provides for a larger number of specialized forms to persist. Habitat structure rather than vegetational composition was also important for reptile species in yet another Australian study (Garden et al. 2007). All of these investigations (Kitchener et al. 1980; Sarre et al. 1995; MacNally and Brown 2001; Martin and Lopez 2002; Santos et al. 2007) suggest that microhabitat requirements are critical to the persistence of squamates in preserves. Our results offer long-term data to support this notion: though the Common Chuckwalla might be classified as an extreme specialist with respect to habitat preference (Lappin et al. 2006), it continues to inhabit the Phoenix Mountains, due in part to the continued presence of rocky outcrops used for basking and refuge from predators. Koenig et al. (2001) suggested that unique aspects of the ecology of Blue-tongued Skinks helped them survive in urban settings. Similarly, Common Chuckwallas may persist in even small preserves given the availability of appropriate microhabitats (rock outcrops with sufficient crevices for refuges). This may be a common occurrence for saxicolous squamates (Fischer et al. 2005): in some settings rocky areas may be the least likely area of a preserve to be impacted by human activity. By contrast, Bonier et al. (2007) showed that birds persisting in urban areas had broader environmental tolerance than rural congeners. It may be that the more restricted microhabitat preferences of chuckwallas allow them to persist while other large lizards of the Sonoran Desert inhabiting open areas have declined (Sullivan and Flowers 1998) in these same preserves. The steep, rocky slopes of the Phoenix Mountains are often the last to be impacted by human recreational activities. If rock outcrops remain undisturbed, chuckwallas may have a better chance than more generalized lizards occupying open areas and lacking a unique escape behavior (Lappin et al. 2006) utilized in rocky microhabitats. Unfortunately, although off-trail hiking is prohibited in the preserves of the Phoenix Mountains, rock climbing occurs on larger cliff sites with some regularity (pers. obs.; Fig. 2).

The repeated sampling of fecal droppings of Common Chuckwallas at one site in the Phoenix Mountains indicates that this technique has utility for monitoring populations. Interestingly, increasing the number of surveyors increased the variability of counts, possibly because student surveyors misidentified some droppings.

Alternatively, surveys by large groups may have simply provided a more accurate estimate than those of smaller groups. Regardless of this variation, it appears that this large lizard is able to withstand isolation in relatively small preserves (e.g., less than two or three km^2), at least over the time span of our study. Additional monitoring will be necessary to evaluate other possible impacts (e.g., lack of gene flow) of the structure of the Phoenix Mountain Preserves on these lizards.

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LITERATURE CITED

Atwood, T.C., H.P. Weeks, and T.M. Gehring. 2004. Spatial ecology of Coyotes along a suburban-to-rural gradient. Journal of Wildlife Management 68:1000-1009.

Bonier, F., P.R. Martin, and J.C. Wingfield. 2007. Urban birds have broader environmental tolerance. Biology Letters 3:670-673.

Brown, D.E. (Ed.). 1982. Biotic Communities of the American Southwest, United States and Mexico. University of Arizona Press, Tucson, Arizona, USA. .

Brueckner, J.K. 2000. Urban sprawl: Diagnosis and remedies. International Regional Science Review 23:160-171

Faeth, S.H., P.S. Warren, E. Shochat, and W. Marussich. 2005. Trophic dynamics in urban communities. Bioscience 55:399-407.

Fischer, J., D.B. Lindenmayer, S. Barry, and E. Flowers. 2005. Lizard distribution patterns in the Turmut fragmentation “Natural Experiment” in south-eastern Australia. Biological Conservation 123:301-315.

Garden, J.G., C.A. McAlpine, H.P. Possingham, and D. N. Jones. 2007. Habitat structure is more important than vegetation composition for local-level management of native terrestrial reptile and small mammal species living in urban remnants: A case study from Brisbane. Austral Ecology 32:669-685.

Goffette-Nagot, F. 2000. Chapter 9: Urban spread beyond the city edge. Pp 338-339 *In* Economics of Cities: Theoretical Perspectives. Huriot, J., and J. Thisse (Eds). Cambridge University Press, New York, New York, U.S.A.

Glista, D.J., T.L. DeVault, and J.A. DeWoody. 2008. Vertebrate road mortality predominantly impacts amphibians. Herpetological Conservation and Biology 3:77-87.

Harveson, P.M., R.R. Lopez, B.A. Collier, and N.J. Silvy. 2007. Impacts of urbanization on Florida Key Deer behavior and population dynamics. Biological Conservation 134:321-331.

Hollander, M., and D.A. Wolfe. 1973. Nonparametric Statistical Methods. John Wiley and Sons, New York, New York, USA.

Kitchner, D.J., A. Chapman, J. Dell, and B.G. Muir. 1980. Lizard assemblage and reserve size and structure in the western Australian wheatbelt—some implications for conservation. Biological Conservation 17:25-62.

Knowles-Yanez, K., C. Moritz, J. Fry, C.L. Redman, M. Bucchin, and P.H. McCartney. 1999. Historic Land Use: Phase I Report on Generalized Land Use. Central Arizona-Phoenix Long-Term Ecological Research (CAPLTER), Arizona State University, Tempe, USA.

Koenig, J., R. Shine, and G. Shea. 2001. The ecology of an Australian Reptile icon: how do Blue-tongued Lizards (*Tiliqua scincoides*) survive in suburbia? Wildlife Research 28:215-227.

Kwiatkowski, M.A., and B.K. Sullivan. 2002a. Geographic variation in sexual selection among populations of an iguanid lizard, *Sauromalus obesus* (= *ater*). Evolution 56:2039-2051.

Kwiatkowski, M.A., and B.K. Sullivan. 2002b. Mating system structure and population density in a polygynous lizard, *Sauromalus obesus* (= *ater*). Behavioral Ecology 13:201-208.

Kwiatkowski, M.A., G.W. Schuett, R.A. Repp, E. Nowak, and B.K. Sullivan. In press. Does urbanization influence the spatial ecology of Gila Monsters in the Sonoran Desert? Journal of Experimental Biology.

Lappin, K.R., P.S. Hamilton, and B.K. Sullivan. 2006. Bite-force performance and head shape in a sexually dimorphic crevice dwelling lizard, the Common Chuckwalla (*Sauromalus ater* [=*obesus*]). Biological Journal of the Linnean Society 88:215-222.

Lindenmayer, D.B., and J. Fischer. 2006. Tackling the habitat fragmentation panchreston. Trends in Ecology and Evolution 22:127-132.

MacNally, R., and G.W. Brown. 2001. Reptiles and habitat fragmentation in the box-ironbark forests of central Victoria, Australia: predictions, compositional change and faunal nestedness. Oecologia 128:116-125.

Martin, J., and P. Lopez. 2002. The effect of Mediterranean dehesa management on lizard distribution and conservation. Biological Conservation 108:213-219.

Marzluff, J.M., and E. Neatherlin. 2006. Corvid response to human settlements and campgrounds: causes,

consequences, and challenges for conservation. Biological Conservation 130:301-314.
Prange, S., and S.D. Gehrt. 2004. Changes to mesopredator-community structure in response to urbanization. Canadian Journal of Zoology 82:1804-1817.
Riley, S.P.D. 2006. Spatial ecology of Bobcats and Gray Foxes in urban and rural zones of a national park. Journal of Wildlife Management 70:1425-1435.
Rosen, P.C., and C.H. Lowe. 1994. Highway mortality of snakes in the Sonoran Desert of southern Arizona. Biological Conservation 68:143-148.
Row, J.R., G. Blouin-Demers, and P.J. Weatherhead. 2007. Demographic effects of road mortality in Black Ratsnakes (*Elaphe obsoleta*). Biological Conservation 137:117-124.
Santos, T., J.A. Diaz, J. Perez-Tris, R. Carbonell, and J.L. Telleria. 2007. Habitat quality predicts the distribution of a lizard in fragmented woodlands better than habitat fragmentation. Animal Conservation 11:46-56.
Sarre, S., G.T. Smith, and J.A. Meyers. 1995. Persistence of two species of gecko (*Oedura reticulata* and *Gehyra variegata*) in remnant habitat. Biological Conservation 71:25-33.
Sullivan, B.K. 2000. Long-term shifts in snake populations: a California site revisited. Biological Conservation 94:321-325.
Sullivan, B.K., and M. Flowers. 1998. Large iguanid lizards of urban mountain preserves in northern Phoenix, Arizona. Herpetological Natural History 6:13-22.
Sullivan, B.K., M.A. Kwiatkowski, and P.S. Hamilton. 2004a. Growth in Sonoran Desert populations of the Common Chuckwalla (*Sauromalus obesus*). Western North American Naturalist 64:137-140.
Sullivan, B.K., M.A. Kwiatkowski, and G.W. Schuett. 2004b. Translocation of urban Gila Monsters: a problematic conservation tool. Biological Conservation 117:235-242.
Sullivan, B.K., P.S. Hamilton, and M.A. Kwiatkowski. 2005. The Arizona Striped Whiptail: past and present. Pp. 145-148 *In* Connecting Mountain Islands and Desert Seas: Biodiversity and Management of the Madrean Archipelgo II. Gottfried, G.J., B.S. Gebow, L.G. Eskew, and C.B. Edminster (Eds.). Proceedings RMRS-P-36, USDA, Forest Service, Rocky Mountain Research Station, 631 p.
Turner, W.R. 2006. Interactions among spatial scales constrain species distributions in fragmented urban landscapes. Ecology and Society 11:6.

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